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Original Article

The effects of dummy/pacifier use on infant blood pressure and autonomic activity during sleep

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ABSTRACT

Background: Dummy/pacifier use is protective for sudden infant death syndrome (SIDS); however, the mechanism/s for this are unknown. As impaired cardiovascular control may be the underlying cause of SIDS, we assessed the effects of dummy/pacifier use on cardiovascular control during sleep within the first 6 months of life.
Methods: Term infants, divided into dummy/pacifier users and non-dummy/pacifier users, were studied at 2–4 weeks ($n = 27$), 2–3 months ($n = 35$) and 5–6 months ($n = 31$) using daytime polysomnography. Heart rate, blood pressure (BP), heart rate variability (HRV), blood pressure variability (BPV), and baroreflex sensitivity (BRS) were measured in triplicate 1–2-min epochs during quiet and active sleep in the supine and prone positions.
Results: Overall, during the non-sucking periods, in the prone position, the BP was higher (10–22 mmHg) in dummy/pacifier users compared to non-users at 2–4 weeks and 5–6 months ($p < 0.05$ for both). HRV and BRS were higher in dummy/pacifier users compared to non-users at 2–4 weeks ($p < 0.05$). Active sucking increased HRV and BPV, consistent with increased sympathetic activity in dummy/pacifier users.
Conclusions: Higher BP and HRV in dummy/pacifier users indicate increased sympathetic tone, which may serve as a protective mechanism against possible hypotension leading to SIDS; however, these effects were not apparent at 2–3 months, when the risk of SIDS is highest.

1. Introduction

Despite the dramatic decline in the incidence of the Sudden Infant Death Syndrome (SIDS), >2500 infants die in the USA each year and SIDS remains the leading cause of perinatal death in Western countries [1]. Evidence from cardiorespiratory recordings prior to death suggests that SIDS occurs during sleep and may be due to a failure of autonomic cardiovascular control to compensate for a profound hypotension in conjunction with a failure to arouse from sleep [2]. In support of this hypothesis, prone sleeping, the major risk factor for SIDS, is associated with an impaired control of both heart rate (HR) and blood pressure (BP), and this is most marked at 2–3 months of age when the risk of SIDS is greatest [3,4]. While there has been much effort to understand how major risk factors, such as prone sleeping, contribute to the fatal event of SIDS, there has been little research directed at factors known to reduce the risk of SIDS. In 1979, it was first suggested that dummy/pacifier use might decrease SIDS risk [5], and this suggestion was later supported by further studies [6–13]. A meta-analysis in 2005 reported a 50% reduction in SIDS among dummy/pacifier users in the last sleep compared to a control group [14] and subsequent studies have confirmed these findings [15,16]. Two more recently published case–control studies have also found dummies/pacifiers to be protective [17,18]. Only one small study has failed to identify a significant protective effect [19].

The American Academy of Pediatrics recommended the use of a dummy/pacifier in 2005 [20]. This recommendation has been quite controversial, and not all countries have adopted this approach. In part, the hesitation to recommend a dummy/pacifier has been due to the lack of understanding of the mechanisms through which they provide protection [21] and the concern that dummy/pacifier use may adversely impact breastfeeding [22].

Abbreviations: SIDS, Sudden Infant Death Syndrome; HRV, Heart rate variability; BPV, Blood pressure variability; BRS, Baroreflex sensitivity; QS, Quiet sleep; AS, Active sleep; ECG, Electrocardiogram; LF, Low frequency; HF, High frequency; LF/HF, Low-frequency/high-frequency ratio.

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To date, there has only been one study on the effects of dummy/pacifier use on cardiovascular control of HR, and this suggested that sucking on a dummy/pacifier was associated with increased sympathetic activation during sleep [23]. No studies have investigated the impact of dummy/pacifier use on BP or autonomic BP control. The most recent epidemiological study identified that dummy/pacifier use provided the greatest protection to infants in the prone sleeping position [18]; however, no physiological studies have examined dummy/pacifier use in this position to date.

We aimed to assess HR and BP and their control during prone and supine sleep in infants who regularly used a dummy/pacifier and those who did not, and to assess the effect of active sucking in dummy/pacifier users across the first 6 months after birth when most SIDS occurs. We hypothesized that BP and HR would be elevated in dummy/pacifier users and cardiovascular control improved in the prone sleeping position.

2. Methods

Ethical approval was granted by the Southern Health and Monash University Human Research Ethics Committees. No monetary incentive was provided for participation, and written parental consent was obtained.

2.1. Subjects

Thirty-seven healthy term infants (17 males and 20 females) born at 38–42 weeks of gestational age were studied. Infants were recruited prior to birth via advertisements in staff newsletters at the Monash University and the Monash Medical Centre, or were recruited after birth in person from both private (Jesse Macpherson Private Hospital) and public wards at the Monash Medical Centre. Birth weights ranged from 2900 to 4615 g (mean 3623 ± 60 g, mean ± standard error of mean (SEM)), and the Apgar scores ranged from 9 to 10 (median 9) at 5 min. All infants were born to mothers who did not smoke during or after pregnancy and all routinely slept supine at home. Dummy/pacifier use was self-selected by the parent and the infant; thus, there was no control over which infants were provided with a dummy/pacifier or for how long the infant used the dummy/pacifier over the first 6 months after birth.

2.2. Polysomnography and BP measurement

Daytime polysomnographic studies (0900–1600) were performed at 2–4 weeks, 2–3 months, and 5–6 months as described previously [24,25]. Prior to each recording, the infant's date of birth, gender, age, birth weight, weight at study, and postal code were recorded.

Each infant was made to sleep in both the prone and supine sleeping positions. The initial starting position was randomized and changed between morning and afternoon sleep periods that were interrupted by a midday feed. At the time of the study, the infants were constantly monitored by the bedside staff to ensure that, when prone, the infant's head was never face down or buried in the bedding and always open to the air. Skin and room temperature were constantly monitored along with HR, oxygen saturation, and breathing respiratory movements by a second staff member outside of the monitoring room.

Electroencephalogram, electro-oculogram, sub-mental electromyogram, electrocardiogram, thoracic and abdominal breathing movements, arterial blood oxygen saturation, and abdominal skin temperature were attached to the infants during the routine morning feed. The BP was recorded using a photoplethysmographic cuff (Finometer™, FMS, Finapres Medical Systems, Amsterdam, the Netherlands) referenced to heart level placed around the infant's wrist as described previously [26]. Beat–beat BP measurements were made in 1–2-min epochs for the duration of each sleep cycle, with 5–8 min being recorded in each infant for each sleep state in each position. The sleep state was defined as quiet sleep (QS) or active sleep (AS) [27,28].

Data were recorded at 512 Hz (Compumedics E-Series Sleep Recording system, Compumedics Limited, Abbotsford, VIC, Australia) and exported via European Data Format to analysis software (Chart 7.2, ADInstruments, Sydney, NSW, Australia).

2.3. Data analysis

The infants' age and weight were averaged at each age studied. The socio-economic status was determined using the Australian Bureau of Statistics Socioeconomic Indexes for Areas 2011 based on the postal code [29]. This index provides a score that is based on key variables, including household income, education, occupation and ethnicity. The lower the index value, the greater the disadvantage for the residential area.

In dummy/pacifier users, sucking was confirmed via video recordings and defined if (1) the dummy/pacifier was in the infant's mouth and (2) there was a clear increase in the electromyograph (EMG) during each sucking event. Data were averaged over 2-min epochs in each sleep state, sleeping position and postnatal age (PNA). In dummy/pacifier users, data were grouped for non-sucking epochs and sucking epochs at each PNA.

2.3.1. Assessment of autonomic control

Spectral analysis techniques were used to assess the autonomic control of HR, BP and baroreflex function. The autonomic nervous system mediates oscillations in HR and BP predominantly in the low-frequency (LF) and high-frequency (HF) spectral ranges. LF changes in HR and BP reflect both sympathetic and parasympathetic activation for HR variability (HRV) [30,31] and sympathetic vasomotor modulation for blood pressure variability (BPV) [32–34]. HF HRV is attributed to respiratory-related changes and reflects the parasympathetic modulation of the heart [31]. The HF component of BPV, while influenced by respiration, is also influenced by parasympathetic activity [32,33]. The ratio between the LF and HF spectral power (LF/HF) provides a measure of sympathovagal balance [31,35].

2.3.2. Assessment of baroreflex function

The baroreflex is the principal regulatory mechanism for the short-term control of BP and is non-invasively quantified by the assessment of baroreflex sensitivity (BRS) using spontaneous changes in HR and BP [36]. To estimate BRS, a cross-spectral analysis of systolic blood pressure (SBP) and *R–R* interval data was performed using the methods described previously [37]. Briefly, in infants, baroreflex-related changes on HR and BP occur within the LF band (defined as 0.04–0.15 Hz). Using transfer function analysis, the gain between SBP and *R–R* interval was computed within the LF band. The gain represents the ratio of the amplitude of fluctuations in the *R–R* interval over those in SBP and provides an estimate of BRS.

All artefact-free epochs of 1-2 min duration were analysed. The mean arterial pressure (MAP) and HR were calculated via peak detection using Labchart 7.2 (ADinstruments, Sydney, NSW, Australia). For HRV, BPV and BRS, SBP and *R–R* interval were determined via peak detection and Fast Fourier transformation performed to compute the spectral power for SBP and *R–R* series using MATLAB (Mathworks, Natick, MA, USA) [3,4,37]. For HRV and BPV, the LF (0.04–0.15 Hz) power reflecting baroreflex activity, the HF power (individualized for each infant depending on respiratory frequency), and total power were calculated [35,38]. BRS was calculated using transfer function analysis between SBP and *R–R* interval changes within the LF range [37].

2.4. Statistical analysis

Statistical analysis was performed using SigmaStat (Systat Software Inc, Richmond, CA, USA). To compare between dummy/pacifier users and non-users for age, weight, and socio-economic status, a one-way analysis of variance (ANOVA) with Student–Newman–Keuls post hoc analysis was performed at each PNA. A two-way ANOVA with Student Newman–Keuls post hoc analysis compared the effects of dummy/pacifier use on HR and BP, HRV, BPV and BRS in each sleeping position at each PNA. To compare the effects of active sucking in dummy/pacifier users on HR and BP, HRV, BPV and BRS, a one-way repeated-measures ANOVA with Student–Newman–Keuls post hoc analysis was used. Results are presented as mean ± SEM, with significance taken at the $p < 0.05$ level.

3. Results

As dummy/pacifier use was not consistent in individual infants across the three studies, infants were divided into dummy/pacifier users at the time of each study. At 2–4 weeks and 5–6 months, one infant was excluded at each age due to technical difficulties during the recording. At 2–4 weeks, 2–3 months, and 5–6 months, 16, 21 and 18 infants used a dummy/pacifier, respectively. Of the infants studied, 12 infants never used a dummy/pacifier and 11 infants always used a dummy/pacifier at all three ages. There were no differences between dummy/pacifier users and non-users for age, weight or socio-economic status at any of the studies.

An example of HR and BP changes that occur with dummy/pacifier sucking is presented in Fig. 1.

3.1. Effects of dummy/pacifier use on cardiovascular control: dummy/pacifier users versus non-users

3.1.1. BP and HR

MAP and HR data for each sleep state, sleeping position, and PNA are presented in Fig. 2. In the prone sleeping position, MAP averaged higher in the dummy/pacifier users compared to the non-users at 2–4 weeks during both QS ($p < 0.05$) and AS ($p < 0.05$) (Fig. 2A). This difference in MAP was also observed at 5–6 months (Fig. 2C), with MAP averaging higher in dummy/pacifier users compared to non-users in the prone sleeping position (overall p value <0.05); however, the post hoc analysis could not identify in which sleep state these differences lay. There were no differences between groups in either sleep state at 2–3 months. There was no difference in HR (Fig. 2D, E and F) between infant groups with the exception of 2–4 weeks in QS-supine when HR was lower in the dummy/pacifier users ($p < 0.05$).

3.1.2. Heart rate variability

The effects of dummy/pacifier use on heart rate variability (HRV) are presented in Fig. 3. There were no differences in any of the HRV parameters at either 2–3 months or 5–6 months of age. At 2–4 weeks, the overall HRV was higher in the dummy/pacifier users, reaching statistical significance in QS-supine for HF and Total HRV ($p < 0.05$ for both). In AS-supine, LF, HF, and Total HRV were significantly higher in the dummy/pacifier users compared with non-users ($p < 0.05$ for all). There were no differences in AS or QS in the prone position.

3.1.3. Blood pressure variability

There were no differences identified between the two groups of infants in either sleeping position at any of the ages studied (Table 1).

3.1.4. Baroreflex sensitivity

There were no differences in BRS between the groups in either position at any of the three ages studied, except at 2–4 weeks PNA during QS in the supine position, where BRS was higher in dummy/pacifier users compared to non-users ($p < 0.05$) (Table 2).

3.2. Effects of dummy/pacifier use on cardiovascular control in infants who consistently used a dummy/pacifier

As dummy/pacifier use varied across the study in individual infants with some infants giving up dummy/pacifier use after the first study and others becoming dummy/pacifier users, we reanalysed the data to compare the cardiovascular variables of the subgroups of infants who had never used a dummy/pacifier ($N = 11$) compared to the group who always used a dummy/pacifier at each age ($N = 12$). Our results were similar to those of the initial analysis. MAP again averaged higher in the dummy/pacifier users compared to non-users in the prone sleeping position, reaching significance at 2–4 weeks PNA during both QS and AS ($p < 0.05$ for both) and

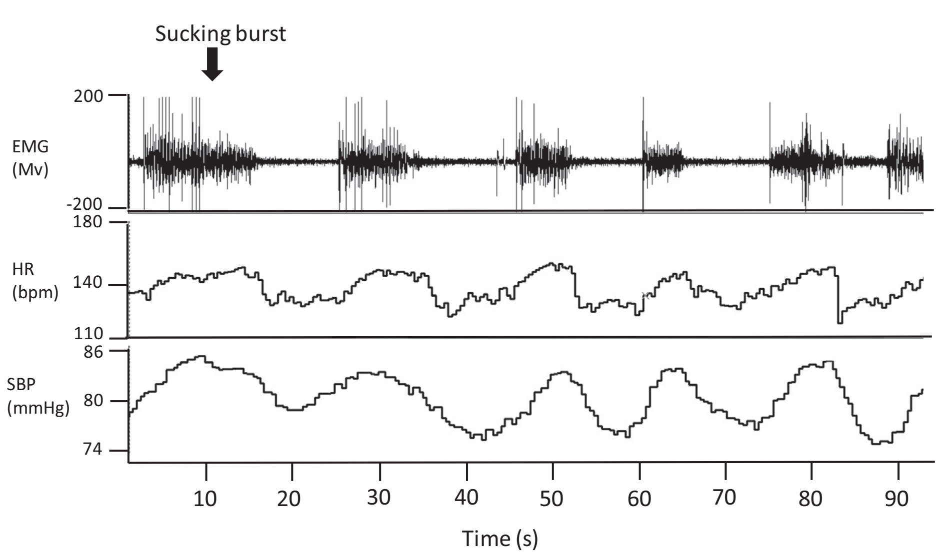

Fig. 1. Example of a recording of sub-mental electromyogram (EMG), heart rate (HR) and systolic blood pressure (SBP) recorded in quiet sleep (QS) while an infant was sucking on a dummy/pacifier at 2–4 weeks postnatal age. Note the increases in EMG correspond to each sucking burst. During each sucking burst, both HR and systolic BP increase and then decrease.

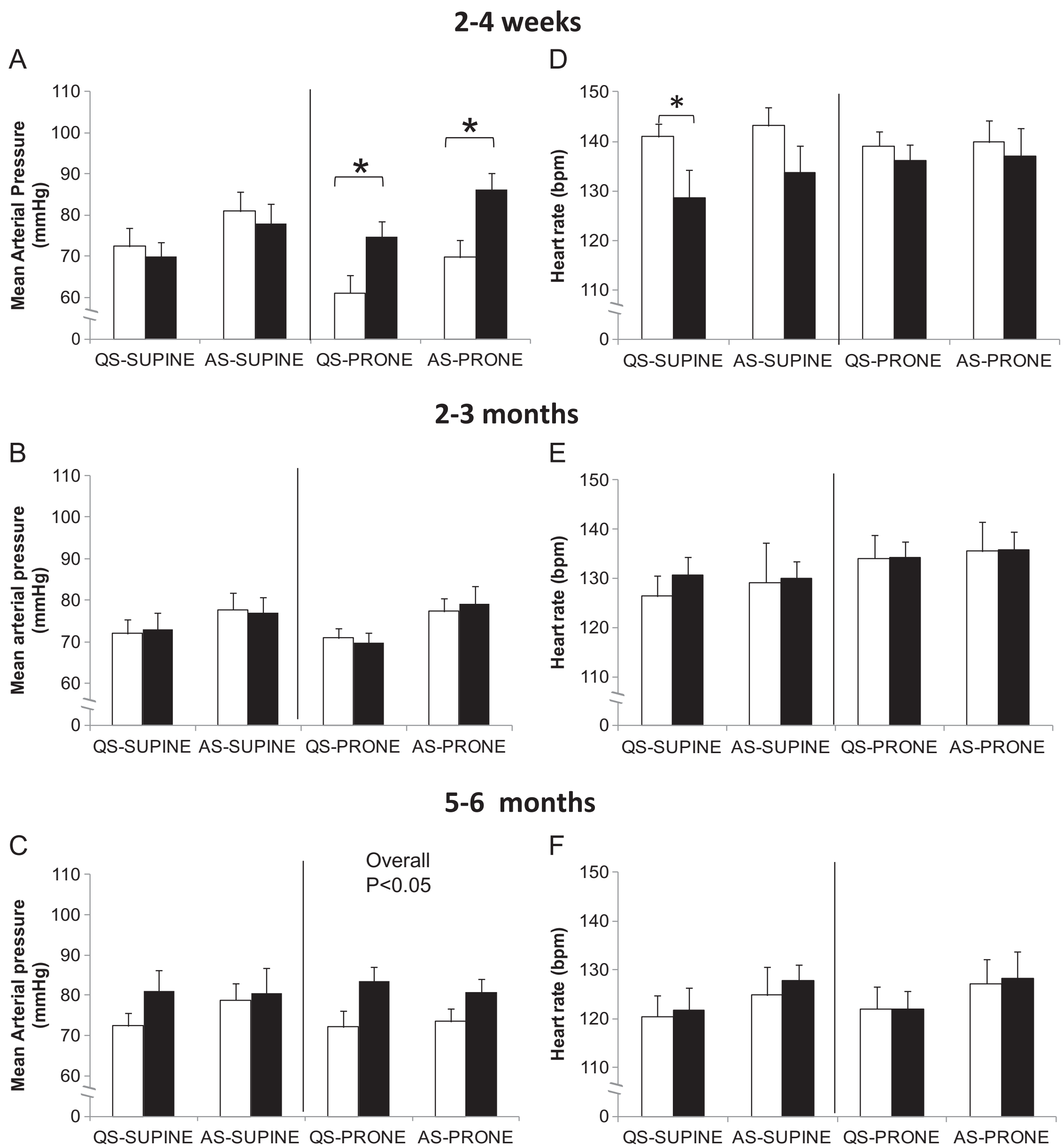

Fig. 2. Mean arterial pressure (A–C) and heart rate (D–F) in dummy/pacifier non-users and users recorded during both quiet sleep (QS) and active sleep (AS) in the prone and supine sleeping positions at 2–4 weeks, 2–3 months, and 5–6 months PNA. White bars represent non-users and black bars represent dummy/pacifier users. $^{*}p < 0.05$ dummy/pacifier non-users versus users.

approaching overall significance at 2–3 months ($p = 0.51$). For HR, HRV, BRS and BPV, the same differences between dummy/pacifier users and non-users were achieved as found in the initial analysis.

3.3. *Effects of active sucking in dummy/pacifier users*

In a subgroup of dummy/pacifier users, who had both active sucking and non-sucking epochs that could be analysed, we compared BP and HR and their control between periods of active sucking and non-sucking. For this analysis, the sleep states and sleep positions at each PNA were combined. For HR and HRV, there were five, 14 and 13 infants for BP, BPV and BRS there were three, five and nine infants at 2–4 weeks, 2–3 months, and 5–6 months, respectively, who had suitable epochs.

3.3.1. *HR and BP*

There were no differences in HR or BP between the sucking and non-sucking epochs at any of the ages studied (Figs. 4A and 4F).

3.3.2. *Heart rate variability*

The effects of active sucking on HRV are presented in Fig. 4B–E. At 2–4 weeks, LF HRV and Total HRV tended to be higher during sucking epochs, (LF HRV $p = 0.051$; Total HRV $p = 0.054$). At 2–3 months, the LF/HF, LF and Total HRV were all higher during the sucking epochs compared to the non-sucking epochs ($p < 0.05$ for all). At 5–6 months, LF/HF, LF, HF and Total HRV were all higher during the sucking epochs compared to the non-sucking epochs ($p < 0.05$ for all).

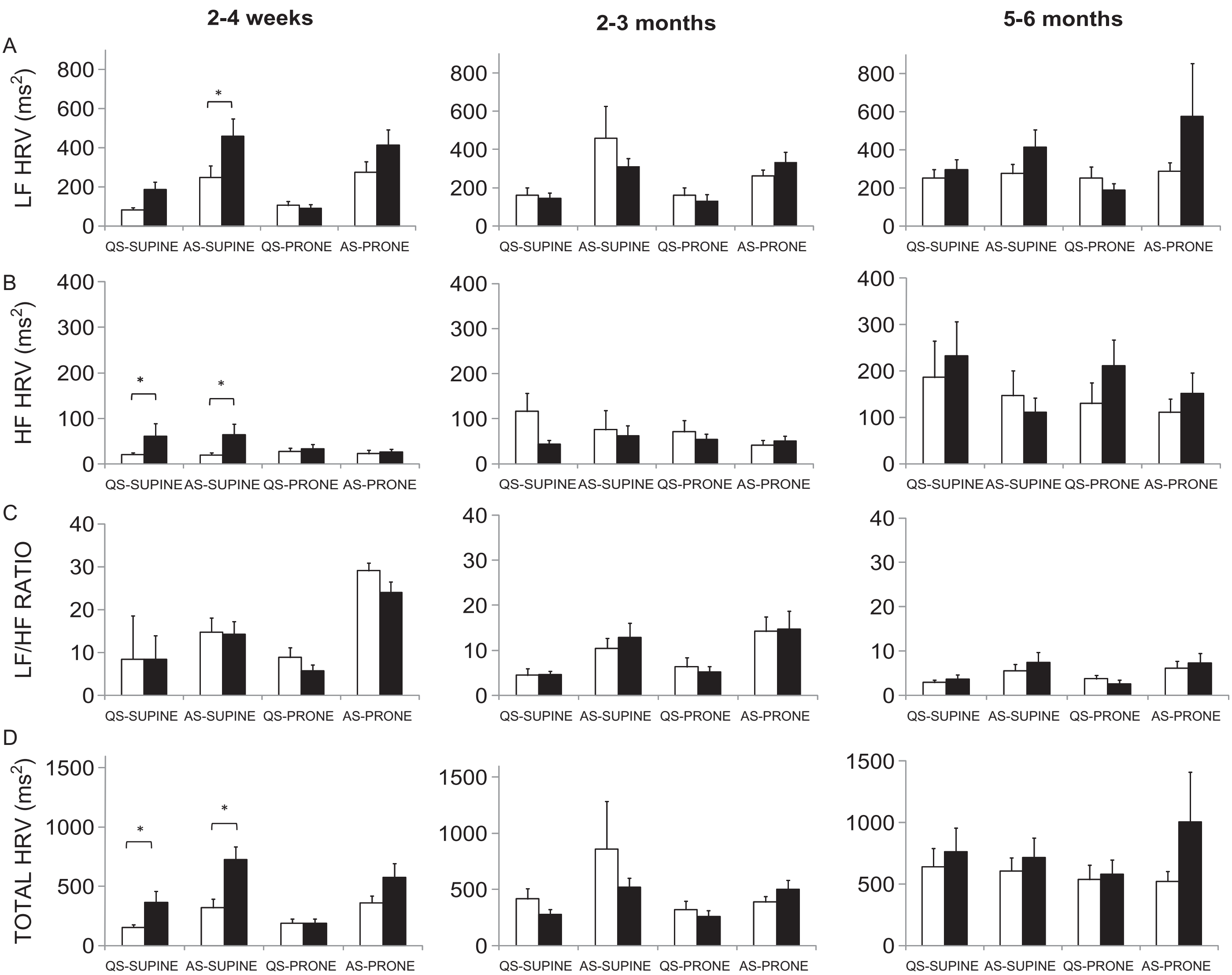

Fig. 3. Spectral indices (A, LF HRV; B, HF HRV; C, LF/HF ratio; and D, Total HRV) of HRV in dummy/pacifier users and non-users recorded during QS and AS in prone and supine sleeping positions at 2–4 weeks, 2–3 months and 5–6 months postnatal age. White bars represent non-users and black bars represent dummy/pacifier users.*$p < 0.05$ non-dummy/pacifier users versus users.

3.3.3. Blood pressure variability

The effects of active sucking on BPV are presented in Fig. 4G–J. At 2–4 weeks, there were no differences in any indices of BPV. At 2–3 months, LF BPV tended to be higher in the sucking epochs compared to the non-sucking epochs (LF BPV, $p = 0.053$). At 5–6 months, LF BPV and LF/HF BPV were both higher during the sucking epochs compared to the non-sucking epochs ($p < 0.05$ for both).

3.3.4. Baroreflex sensitivity

There were no differences in BRS between the sucking epochs and the non-sucking epochs at any of the ages studied.

4. Discussion

Regular dummy/pacifier use has consistently been shown to be associated with a reduced SIDS risk; however, the mechanism for this reduced risk is currently unknown. This was the first study to investigate both BP and HR control in infants who regularly used a dummy/pacifier and those who did not. We hypothesized that to be protective, the use of a dummy/pacifier would increase BP and improve cardiovascular control and this would be most marked in the prone sleeping position. We found that BP was elevated at 2–4 weeks and 5–6 months of age in the prone position; however, at 2–3 months, there were no differences in BP between users and non-users. In addition, dummy/pacifier use increased HRV and BRS at 2–4 weeks of age.

In this study, we also assessed both HR and BP and their control in dummy/pacifier users during both periods of sucking and non-sucking. Consistent with a study [39], we identified that HR was not different between active sucking episodes compared to non-sucking episodes. Although HR was not different, our analysis showed that active sucking increased HRV; specifically, LF, HF, and LF/HF HRV were all higher compared to non-sucking periods at all ages. This suggests that autonomic activity is increased while the infant is actively sucking on a dummy/pacifier. Importantly, a higher LF HRV together with a higher LF/HF suggests that sympathetic activity is increased during active sucking. Our HRV findings are consistent with a previous study, which also showed that LF and LF/HF HRV were higher during active sucking [23].

The rise in sympathetic tone during sucking episodes also appeared to be present in the vasculature, as evidenced by a higher LF and LF/HF BPV at 5–6 months (Fig. 4G and I). We did not find

Table 1
Blood pressure variability (BPV) spectral indices in dummy/pacifier non-users and users assessed in quiet sleep (QS) and active sleep (AS) in both the supine and prone sleeping position at 2–4 weeks, 2–3 months and 5–6 months PNA.

	2–4 weeks		2–3 months		5–6 months	
	Non-users	Users	Non-users	Users	Non-users	Users
QS-supine						
LF/HF	12 ± 4	22 ± 11	9 ± 3	7 ± 3	3 ± 1	13 ± 10
LF BPV ($mmHg^2$)	4 ± 1	4 ± 1	3 ± 1	2 ± 1	2 ± 0	3 ± 1
HF BPV ($mmHg^2$)	0.7 ± 0.2	0.5 ± 0.1	0.8 ± 0.2	0.6 ± 0.2	0.9 ± 0.2	1.3 ± 0.4
Total BPV ($mmHg^2$)	6 ± 1	5 ± 1	5 ± 1	3 ± 1	5 ± 1	5 ± 1
QS-prone						
LF/HF	11 ± 5	14 ± 7	4 ± 1	11 ± 6	6 ± 2	2 ± 0
LF BPV ($mmHg^2$)	3 ± 1	2 ± 0	3 ± 1	2 ± 0	2 ± 0	2 ± 0
HF BPV ($mmHg^2$)	0.8 ± 0.2	0.9 ± 0.3	1.3 ± 0.4	1.0 ± 0.2	0.9 ± 0.2	1.4 ± 0.4
Total BPV ($mmHg^2$)	5 ± 1	4 ± 1	5 ± 1	4 ± 1	4 ± 1	4 ± 1
AS-supine						
LF/HF	8 ± 2	11 ± 2	13 ± 5	4 ± 3	3 ± 1	3 ± 2
LF BPV ($mmHg^2$)	8 ± 4	10 ± 3	4 ± 1	8 ± 1	4 ± 1	4 ± 1
HF BPV ($mmHg^2$)	1.1 ± 0.4	1.0 ± 0.4	0.4 ± 0.1	2.2 ± 0.3	1.9 ± 0.7	2.0 ± 0.7
Total BPV ($mmHg^2$)	12 ± 5	13 ± 4	5 ± 1	13 ± 1	11 ± 0.4	7 ± 1
AS-prone						
LF/HF	16 ± 4	10 ± 4	6 ± 2	10 ± 1	3 ± 1	4 ± 2
LF BPV($mmHg^2$)	9 ± 2	9 ± 2	8 ± 3	5 ± 2	3 ± 1	7 ± 3
HF BPV ($mmHg^2$)	0.9 ± 0.2	1.4 ± 0.4	1.9 ± 0.4	1.1 ± 0.4	1.6 ± 0.4	2.0 ± 0.7
Total BPV ($mmHg^2$)	12 ± 2	12 ± 3	13 ± 4	8 ± 2	6 ± 1	11 ± 4

Spectral power was assessed in the low-frequency (LF, 0.04–0.15 Hz) range and high-frequency (HF, individualized for respiratory rate) range. LF/HF represents sympatho-vagal balance, LF reflects sympathetic activity and HF reflects parasympathetic and respiratory-mediated changes in blood pressure.

these differences in BPV at the earlier ages and speculate that these differences were not achieved at 2–4 weeks and 2–3 months PNA due to the low numbers in these age groups. Nonetheless, taken together, these results suggest that active sucking alters the autonomic activity of both HR and BP, whereby sympathetic activity is increased. However, this rise in sympathetic activity did not affect baroreflex function, as we identified no differences in BRS at any of the ages studied.

A novel finding from this study was that in the prone position, BP was higher overall in dummy/pacifier users compared to non-users at both 2–4 weeks and 5–6 months PNA (Fig. 2). The mechanism responsible for higher BP in dummy/pacifier users is unclear; however, it is possible that active dummy/pacifier sucking may increase the overall sympathetic vascular tone in dummy/pacifier users contributing to increased vascular resistance and thus elevated BP. It is also possible that increased oscillations in BP due to active sucking may improve BRS, keeping BP within tighter limits. In support of this, at 2–4 weeks, when BP was higher in dummy/pacifier users, BRS was also higher (Table 2). However, there were no differences in BRS at 5–6 months where BP was also elevated in dummy/pacifier users, and thus this suggestion does not fully explain the elevated BP in dummy/pacifier users. We also identified that HRV was higher in dummy/pacifier users compared to non-users (Fig. 3); however, this difference was only apparent at 2–4 weeks PNA. There has only been one previous study examining dummy/pacifier use on autonomic HR control during sleep in infancy. This study suggested that dummy/pacifier users had decreased sympathetic activation and increased parasympathetic activation of HR compared to infants who had never used a dummy/pacifier [23], a finding based on dummy/pacifier users having lower LF/HF HRV and higher HF HRV. However, in the current study, we found that at 2–4 weeks there was no difference in the LF/HF HRV between users and non-users and that the LF and HF HRV were both higher in dummy/pacifier users, suggesting that there is no reduction in sympathetic activity. Discrepancies between the previous study by Franco et al. and this study may be due to study design, as their study was performed on infants of varying PNAs (6–18 weeks) and did not take into account the effects of the sleeping position. Furthermore, in our study, we elected to separate infants on the basis of their dummy/pacifier use at the time of the study as this changed over the 6-month study period.

The majority of our findings were significant at 2–4 weeks PNA, which could suggest that dummy/pacifier users are inherently different from non-users; that is, infants who are offered and accept a dummy/pacifier may already have an innate protection. It is possible that dummy/pacifier users may be more arousable than non-users, which was the reason why they are given a dummy/pacifier. Interestingly, studies investigating the effects of dummy/pacifier use on arousal from sleep have produced conflicting findings, with one study demonstrating that dummy/pacifier users were more arousable in AS (tests were not carried out in QS, a sleep state of inherent reduced arousability) than non-users [40]. However, a more recent study has shown no effects on arousability in either AS or QS [41], and thus further studies to examine this hypothesis are required.

Table 2
Baroreflex sensitivity (BRS) (ms/mmHg) in dummy/pacifier non-users and users assessed in quiet sleep (QS) and active sleep (AS) in both the supine and prone sleeping positions at 2–4 weeks, 2–3 months and 5–6 months postnatal age.

	2–4 weeks		2–3 months		5–6 months	
	Non-users	Users	Non-users	Users	Non-users	Users
QS-supine	6 ± 1	9 ± 2*	10 ± 2	7 ± 2	15 ± 3	12 ± 2
QS-prone	7 ± 3	7 ± 1	9 ± 2	10 ± 1	13 ± 3	11 ± 1
AS-supine	6 ± 2	10 ± 2	13 ± 4	9 ± 2	10 ± 1	9 ± 1
AS-prone	7 ± 2	8 ± 1	11 ± 2	6 ± 1	8 ± 1	9 ± 2

* $p < 0.05$ non-users versus users.

4.1. Implications for SIDS

Current evidence suggests that the fatal event of SIDS involves an uncompensated hypotension in association with a failure to arouse from sleep [2]. In support of this contention, the prone sleeping position reduces BP [24], impairs baroreflex function [42], and also impairs arousal responses [43], and these effects were most marked at 2–3 months when the risk of SIDS is greatest. The age range of 2–3 months represents a period when SIDS risk peaks, and about 25% of SIDS deaths occur [44]. However, we found no differences between dummy/pacifier users and non-users in any of the

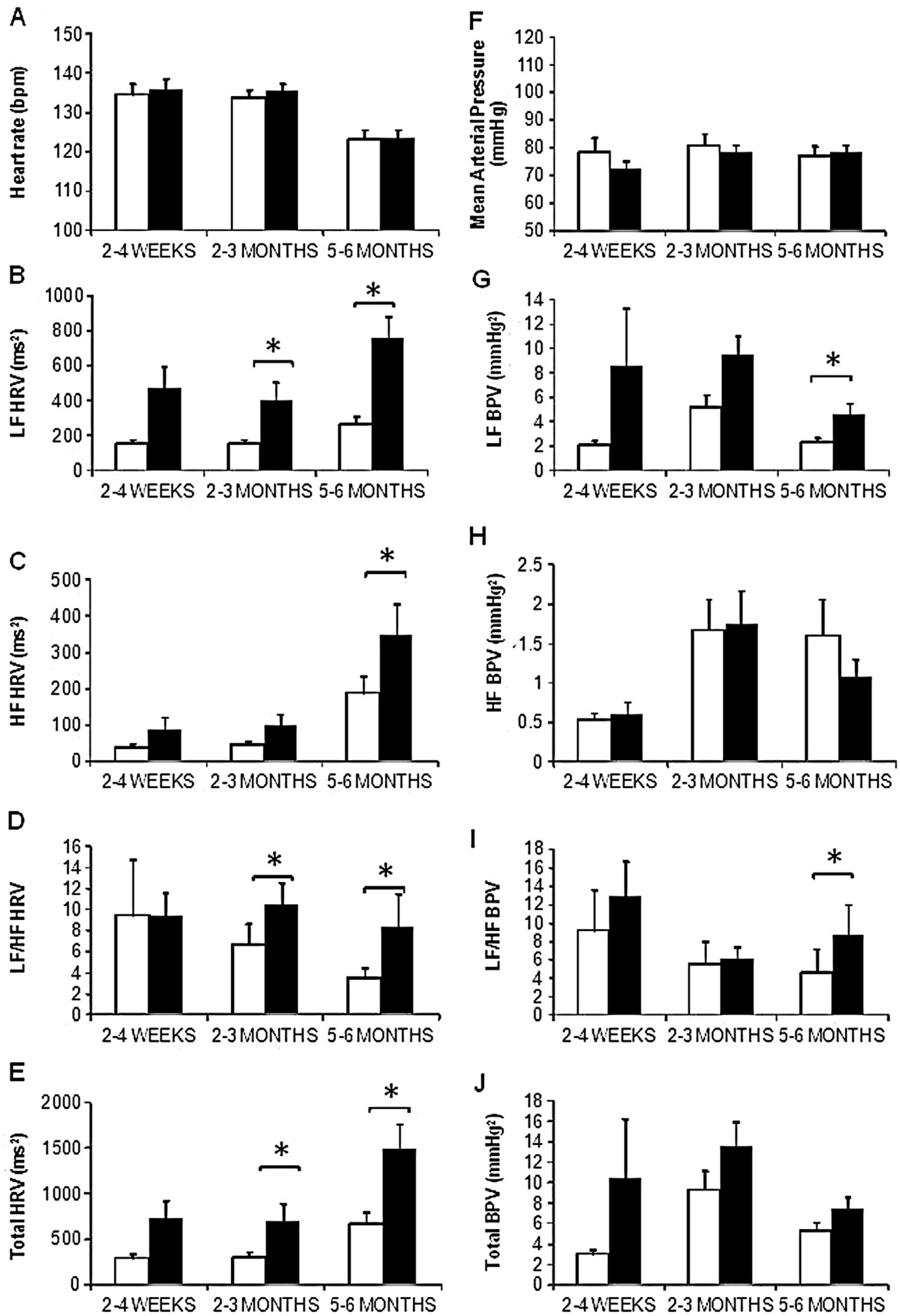

Fig. 4. Compares the effects of active sucking to non-sucking epochs on spectral indices for HRV (A, heart rate; B, LF HRV; C, HF HRV; D, LF/HF HRV; and E, Total HRV) and BPV (F, mean arterial pressure; G, LF BPV; H, HF BPV; I, LF/HF BPV; and J, Total BPV). White bars represent non-sucking epochs and black bars represent active sucking epochs. $^{*}p < 0.05$ non-sucking versus active sucking.

cardiovascular parameters assessed at this age. Thus, changes in cardiovascular control do not explain the mechanism of protection for dummy use at this age. Neuropathological findings in SIDS victims have shown abnormalities in both the brainstem and cerebellar structures [45], which are known to contribute to BP regulation and the coordination of infant sucking [46]. At 2–3 months, the effects of dummy/pacifier use on autonomic cardiovascular control may be reduced as this is a period of transition in the neural organization of central BP regulation. For example, animal studies have shown that cerebellar influences on BP regulation are age dependent, where cerebellar structures are important very early in life, after which a period of transition occurs, with more rostral brain structures serving a greater role with development [47]. It has been suggested that an analogous transitional period in BP regulation may exist in human infants [45] and coincide with the high SIDS risk period (2–3 months), and thus could potentially influence the effect of dummy/pacifier use on autonomic BP regulation.

In contrast to 2–3 months, at 2–4 weeks and 5–6 months, a higher BP in dummy users in the prone position may serve as a protective mechanism against SIDS. This finding is still particularly significant given that a total ≈18% of SIDS deaths occur at 2–4 weeks and 5–6 months [44]. Previously, we have shown that BP is reduced

by major risk factors for SIDS, such as prone sleeping position [24] and preterm birth [48]. BP fluctuations are controlled tightly by the baroreflex; low BP may place infants at or below the linear portion of the baroreflex function curve, which may limit the compensatory HR responses to changes in BP, resulting in a vulnerability to hypotensive events. A higher baseline BP, particularly in the prone sleeping position, may increase the margin of safety against possible hypotension during sleep.

The major confounding factor for potential protective mechanisms of dummy/pacifier use that needs to be addressed is that infants lose their dummy/pacifier soon after falling asleep [39,40]. Thus, to be protective, dummies/pacifiers would need to provide a long-lasting effect on the cardiovascular system that continues after the device had fallen out. Our study showed that dummy/pacifier use increases sympathetic activation during periods of active sucking and dummy/pacifier users have higher baseline BP compared to non-users during non-sucking periods, indicating that it may have long-lasting effects.

4.2. Limitations

There are a number of limitations to this study that must be addressed. We did not record why the infant was provided with a dummy/pacifier, and infants were grouped according to use at the time of each study. However, when we analysed the data for infants who had never used a dummy/pacifier compared to those who consistently had, we had similar findings. To overcome the limitations of both innate protection and consistent dummy pacifier use, a randomized controlled trial would be required. However, even if an infant is offered a dummy/pacifier, depending on the infant's temperament, the infant may not accept it, and thus such an approach may not be feasible.

We elected to perform daytime polysomnographic studies to maximize the recruitment rate. Performing sleep studies during the day rather than night may be viewed as a potential limitation in our study design as the majority of SIDS deaths occur at night. However, epidemiological studies by Mitchell et al. [49] now show that the prone sleeping position carries a greater risk for SIDS during the day than at night. Thus, we are confident that our findings relate to understanding the potential protective effects of dummies/pacifiers while accounting for the major risk factor for SIDS, the prone sleeping position. Finally, at the time of the study, we did not record maternal or familial factors such as maternal diet and ethnicity, which could also contribute to differences in BP between dummy/pacifier users and non-users.

5. Conclusions

This study identified that active sucking of a dummy/pacifier alters cardiovascular control. Specifically, the BP was higher at 2–4 weeks and 5–6 months, and HRV was also higher at 2–4 weeks in dummy/pacifier users compared to non-users, indicating that sympathetic tone may be higher. A higher sympathetic tone may protect infants from possible hypotension during sleep and thus may play a protective role in the fatal event of SIDS. However, we cannot discount that dummy/pacifier users may be innately different; thus, the protective mechanism/s of dummy/pacifier use deserves further study.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.07.011.

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